Orion Ascent Abort 2 (AA-2) Overview

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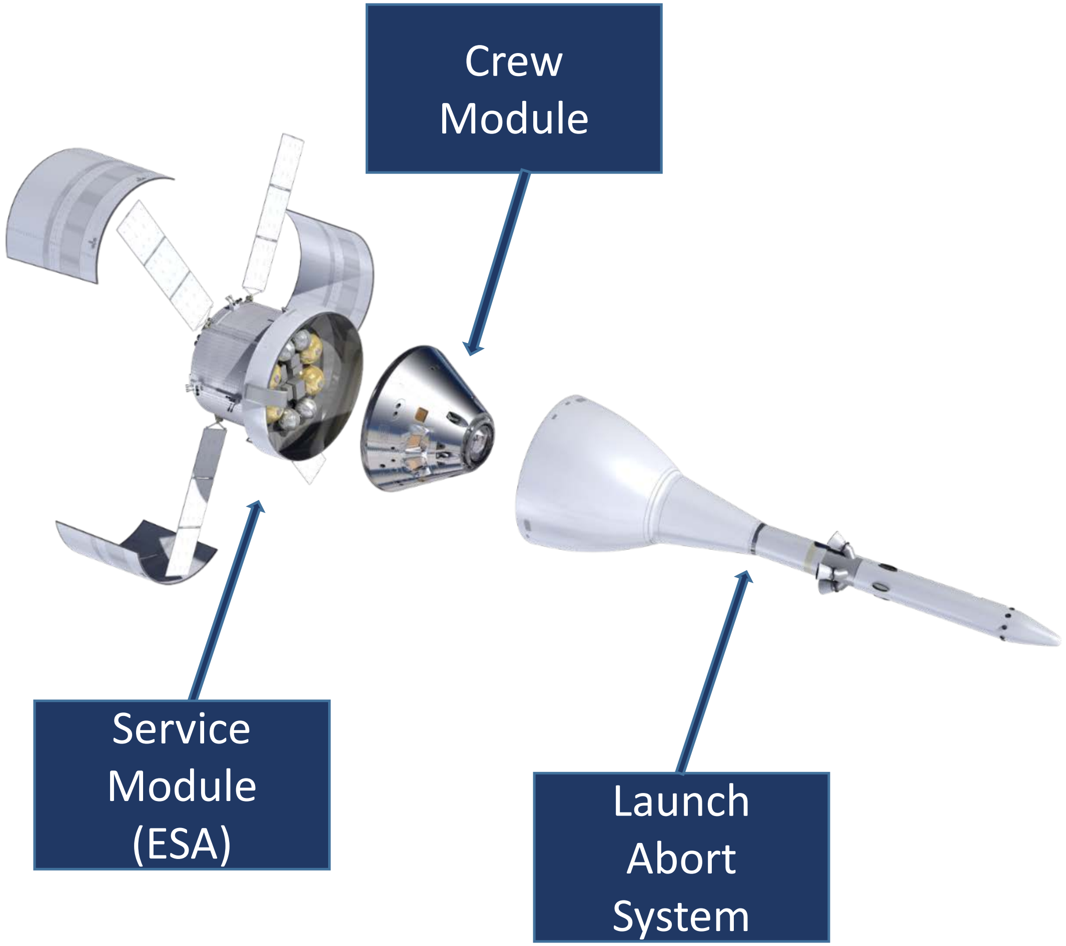
Image credit: NASA

Summary

- What is the Orion Multipurpose Crew Vehicle?
- Brief History of Manned Spacecraft Abort/Escape Systems
- Previous Orion Flight Tests
- AA-2
    - Operations Concept
    - Mission Objectives
    - Mission Team
    - Flight Test Vehicle
    - Mission Animation
- Questions???
- Sources

What is the Orion Multipurpose Crew Vehicle?



- A new human spacecraft that will usher in a new era of space exploration
- Designed to meet the evolving needs of our nation’s deep space exploration program for decades to come
- It will be the safest, most advanced spacecraft ever built, flexible and capable enough to take us to a variety of destinations

Brief History of Manned Spacecraft Abort/Escape Systems

- Mercury

  July 1958:

  Dr. Maxime “Max” Faget conceived the tractor configuration Launch Escape System (LES) for the Mercury Capsule.

  March 8, 1959:

  The first Mercury LES test was conducted at Wallops Island.

  March 11, 1959:

  The first full-scale Mercury pad abort test was conducted also at Wallops Island.

  July 22 & 28, 1959:

  Successful Mercury boilerplate pad aborts, both with a production configuration LES.

  May 9, 1960:

  Successful Mercury Pad Abort 1 using the first production Mercury spacecraft and a production LES. The objectives included evaluation of the LES performance, the parachute and landing system, and off-the-pad abort recovery operations.

  November 21, 1960:

  During unsuccessful attempt to launch Mercury-Redstone 1 (MR-1), the LES recovered the unmanned Mercury spacecraft undamaged.

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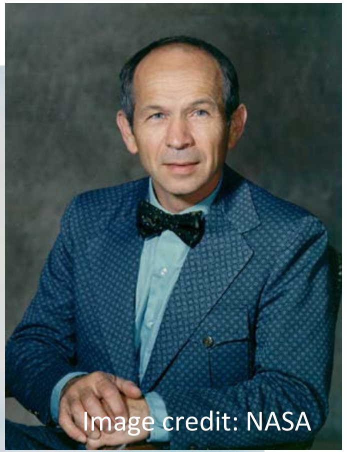
Image credit: NASA

Brief History of Manned Spacecraft Abort/Escape Systems

- Mercury Little Joe Flight Tests
  - LJ-1 – August 21, 1959:
    - Failed launch. About a half-hour before scheduled launch, the escape rocket fired and pulled the Mercury spacecraft away from the launch pad.
  - LJ-6 – October 4, 1959:
    - Successful test of uninstrumented boilerplate spacecraft and inert LES. Apogee of 60 km (37 mi) and a range of 127 km (79 mi).
  - LJ-1A – November 4, 1959:
    - Repeat of LJ-1. LES activation delayed due to unknown cause. Apogee of 14.5 km (9 mi) and a range of 18.5 km (11.5 mi).
  - LJ-2 – December 4, 1959:
    - Carried the rhesus monkey, Sam, to an apogee of 88 km (55 mi).
  - LJ-1B – January 21, 1960:
    - Successful repeat of LJ-1. Carried the rhesus monkey, Miss Sam, to an apogee of 15 km (9.3 mi) and a range of 18.9 km (11.7 mi).
  - LJ-5 – November 8, 1960:
    - Unsuccessful qualification test of production Mercury spacecraft #3. Apogee of 16.2 km (10.1 mi) and range of 20.9 km (13 mi).
  - LJ-5A – March 18, 1961
    - Unsuccessful repeat of LJ-5 using production Mercury spacecraft #14. Spacecraft recovered with only minor damage. Apogee of 12 km (7.7 mi) and range of 29 km (18 mi).
  - LJ-5B – April 28, 1961
    - Successful repeat of LJ-5 using production Mercury spacecraft #14A, which was recovered. Apogee of 4.5 km (2.8 mi) and range of 14 km (9 mi).


Image credit: NASA


Image credit: NASA

Brief History of Manned Spacecraft Abort/Escape Systems

- Apollo

QTV – August 28 1963:

Little Joe II Qualification Test Vehicle – successful launch at WSMR. Apogee 4.7 km (2.9 mi) and range 3.5 km (2.2 mi).

PA-1 – November 7, 1963:

Successful first pad abort at WSMR. Production LES and Apollo boilerplate spacecraft BP-06. Apogee 2.8 km (1.8 mi) and range 2.5 km (1.6 mi).

A-001 – May 13, 1964:

Successful transonic abort test using Apollo boilerplate spacecraft BP-12 on May 13. Apogee 9.1 km (5.6 mi) and range 6.8 km (4.2 mi).

AS-101 – May 28, 1964:

Sixth Saturn I launch, successful launch and exit environment test on May 28 at KSC. First LES jettison from a Saturn launch vehicle.

AS-102 – September 18, 1964:

Seventh Saturn I launch, successful launch and exit environment test, Sep 18 at KSC. LES jettison performed with escape motor and pitch control motor.

A-002 – December 8, 1964:

Successful max dynamic pressure abort Dec 8 at WSMR using Apollo boilerplate spacecraft BP-23. Apogee 15.4 km (9.5 mi) and range 10 km (6.2 mi).

A-003 – May 19, 1965:

Planned high altitude abort. Little Joe II malfunction resulted in successful, unplanned, low-altitude, out-of-control abort on May 19 at WSMR using Apollo boilerplate spacecraft BP-22. Apogee 6 km (3.8 mi) and range 5.6 km (3.5 mi).

PA-2 – June 29, 1965:

Successful second pad abort on Jun 29 at WSMR using Apollo boilerplate spacecraft BP-23A. Apogee 2.8 km (1.8 mi) and range 2.3 km (1.4 mi).

A-004 – January 20, 1966:

Successful power-on tumbling boundary abort on Jan 20 at WSMR using Apollo Command Module CM-002. Apogee 23.8 km (14.8 mi) and range 34.6 km (21.5 mi).

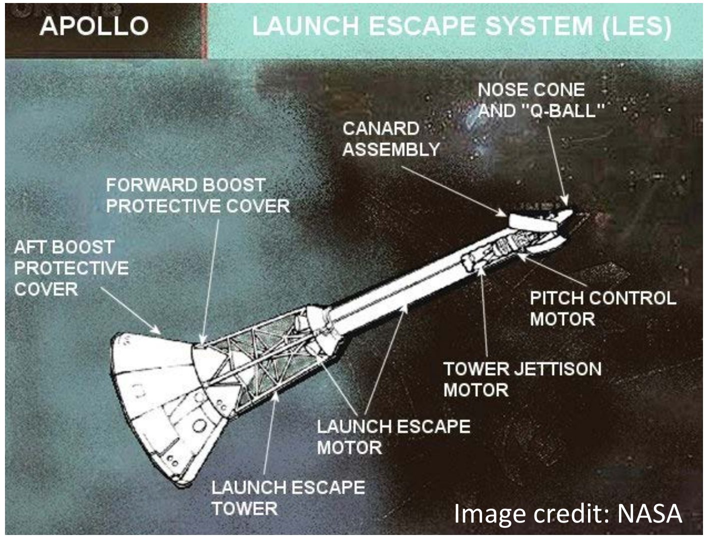

Image credit: NASA


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Brief History of Manned Spacecraft Abort/Escape Systems

- Actual Abort/Escape System Emergency Use
  - Soyuz

    September 26, 1983

    - A fire broke out on the launch pad shortly before launch.
    - Ground controllers activated the escape system via radio command.
    - Cosmonauts Vladimir Titov & Gennadi Strekalov were lifted free of the launch vehicle and safely deposited about 4 km (2.5 mi) from the exploded booster.
    - Peak acceleration was 14 to 17 Gs

Image credit: NASA

Brief History of Manned Spacecraft Abort/Escape Systems

- Actual Abort/Escape System Emergency Use
  - Soyuz FG

    October 11, 2018

    - Booster malfunction 2:02 after liftoff
      - Immediately following strap-on separation

Jim Bridenstine
@JimBridenstine
Follow

.@NASA astronaut Nick Hague and Russian cosmonaut Alexey Ovchinin are in good condition following today's aborted launch. I'm grateful that everyone is safe. A thorough investigation into the cause of the incident will be conducted. Full statement below:

Statement on Soyuz MS-10 Launch Abort

The Soyuz MS-10 spacecraft launched from the Baikonur Cosmodrome in Kazakhstan to the International Space Station at 4:40 a.m. EDT Thursday, October 11 (2:40 p.m. in Baikonur) carrying American astronaut Nick Hague and Russian cosmonaut Alexey Ovchinin. Shortly after launch, there was an anomaly with the booster and the launch ascent was aborted, resulting in a ballistic landing of the spacecraft.

Search and rescue teams were deployed to the landing site. Hague and Ovchinin are out of the capsule and are reported to be in good condition. They will be transported to the Gagarin Cosmonaut Training Center in Star City, Russia outside of Moscow.

NASA Administrator Jim Bridenstine and the NASA team are monitoring the situation carefully. NASA is working closely with Roscosmos to ensure the safe return of the crew. Safety of the crew is the utmost priority for NASA. A thorough investigation into the cause of the incident will be conducted.

Image credit: NASA

Brief History of Manned Spacecraft Abort/Escape Systems

- Commercial Crew Program

SpaceX:

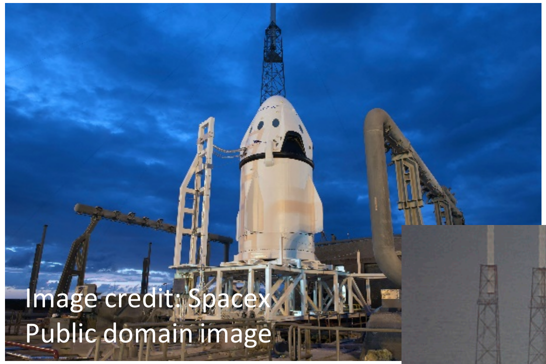
- Pusher configuration escape system with eight SuperDraco engines.
- Pad Abort from Space Launch Complex 40 (SLC-40) at KSC on May 6, 2015
- In-flight abort test planned prior to the first crewed orbital flight

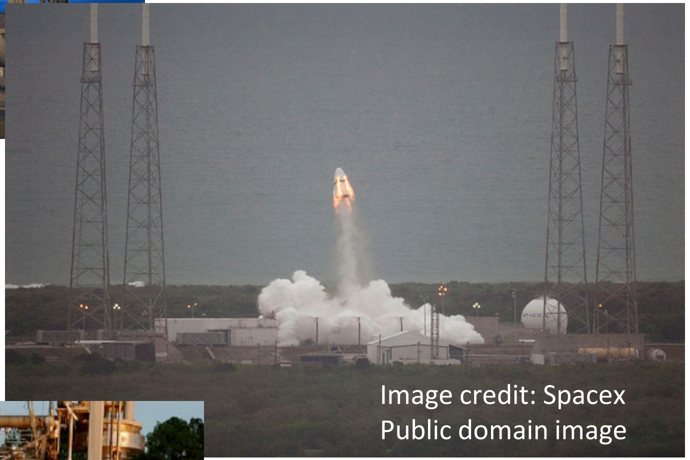
Boeing CST-100:

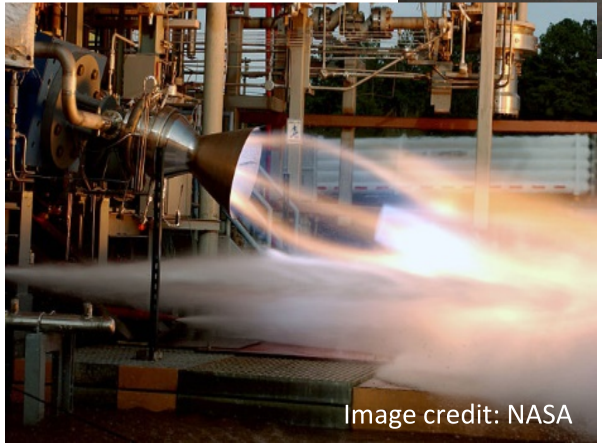
- Pusher configuration escape system with one hypergolic launch abort engine (LAE) derived from the RS-88.
- Pad Abort planned from Cape Canaveral AFS prior to first crewed flight

Blue Origin New Shepard:

- Pusher configuration escape system with one Aeroject Rocketdyne Crew Capsule Escape Solid Rocket Motor (CCE SRM)
- Completed pad abort test October 19, 2012 at its West Texas launch site.
- Completed in-flight abort test October 5, 2016 at its West Texas launch site
- Completed high-altitude in-flight abort test July 18, 2018 at its West Texas launch site







Brief History of Manned Spacecraft Abort/Escape Systems

- Indian Space Research Organisation (ISRO)
  - Tractor configuration escape system with seven solid rocket motors
  - Pad Abort from Satish Dhawan Space Centre, Sriharikota, India on July 5, 2018

Previous Orion Flight Tests
Pad Abort 1 (PA-1)

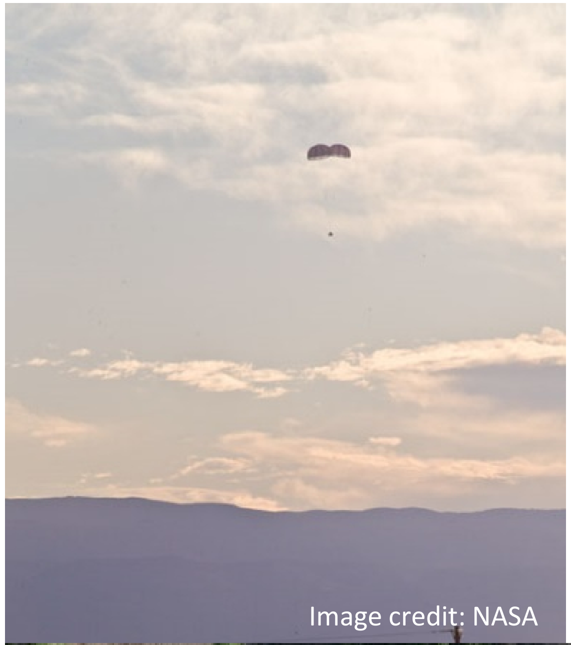


Image credit: NASA


Image credit: NASA


Image credit: NASA

- Pad Abort 1 (PA-1)
  - First fully integrated flight test of the Orion Launch Abort System
  - Launched May 6, 2010 from Launch Complex 32 East, White Sands Missile Range, NM
  - Successful integrated demonstration of abort motor, attitude control motor, jettison motor, & parachute system
  - Time of flight: 134 seconds
  - Zero to Mach 0.7: ~2.5 seconds
  - Apogee: 3.2 km (2.0 mi/10,386 ft)
  - Range: 2.1 km (1.3 mi/6,912 ft)

Previous Orion Flight Tests

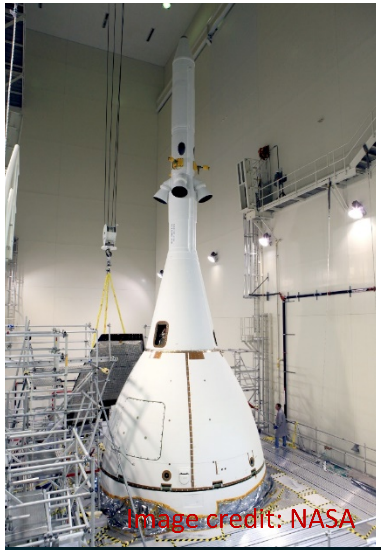


Image credit: NASA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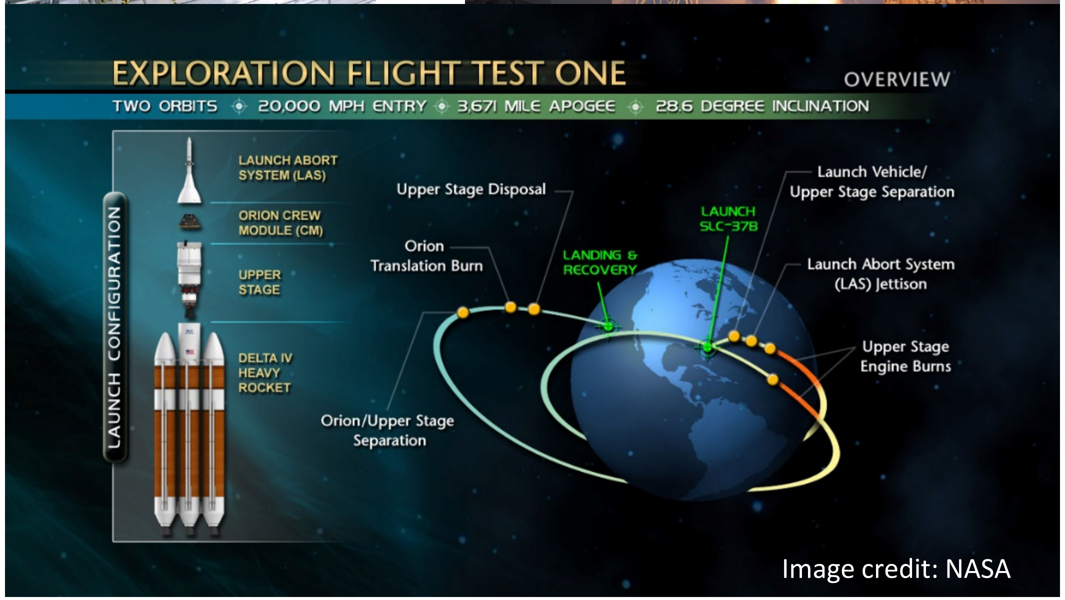


Image credit: NASA

- Exploration Flight Test 1 (EFT-1)
  - Launched December 5, 2014 from SLC-37B, Cape Canaveral AFS, FL on a Delta IV Heavy launch vehicle
  - Successful LAS Jettison
  - Successful reentry from a simulated lunar reentry condition


Image credit: NASA

Previous Orion Flight Tests
Capsule Parachute Assembly System (CPAS)

Image credit: NASA

U.S. Air Force photo by Christopher A. Okula

Image credit: NASA

- CPAS Development and test began in 2006
- Development testing concluded in January 2016 after 17 engineering development airdrop tests
- Eighth and final required parachute qualification airdrop test completed September 12, 2018

see NASACPAS on YouTube

AA-2 Operations Concept
Flight Operations

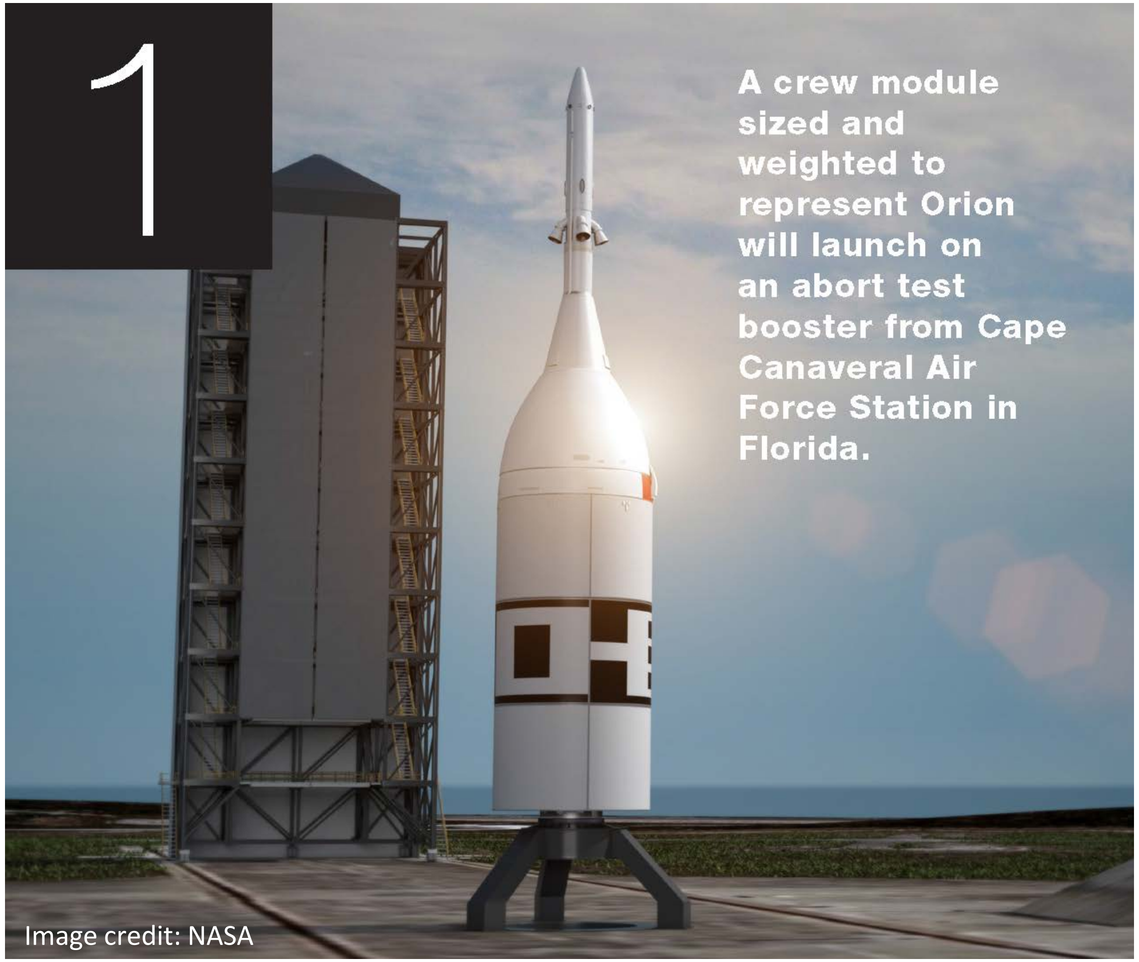


Image credit: NASA

- In July 2019, Orion is scheduled to undergo a full-stress test of the LAS, called Ascent Abort Test 2 (AA-2)
- Objective: demonstrate ability of LAS to pull crew to safety during ascent
- As this was written, AA-2 team was currently conducting final integrated testing of the Launch Vehicle at SLC-46
- AA-2 will be launched from Space Launch Complex 46 (SLC-46) at Cape Canaveral Air Force Station

AA-2 Operations Concept
Flight Operations

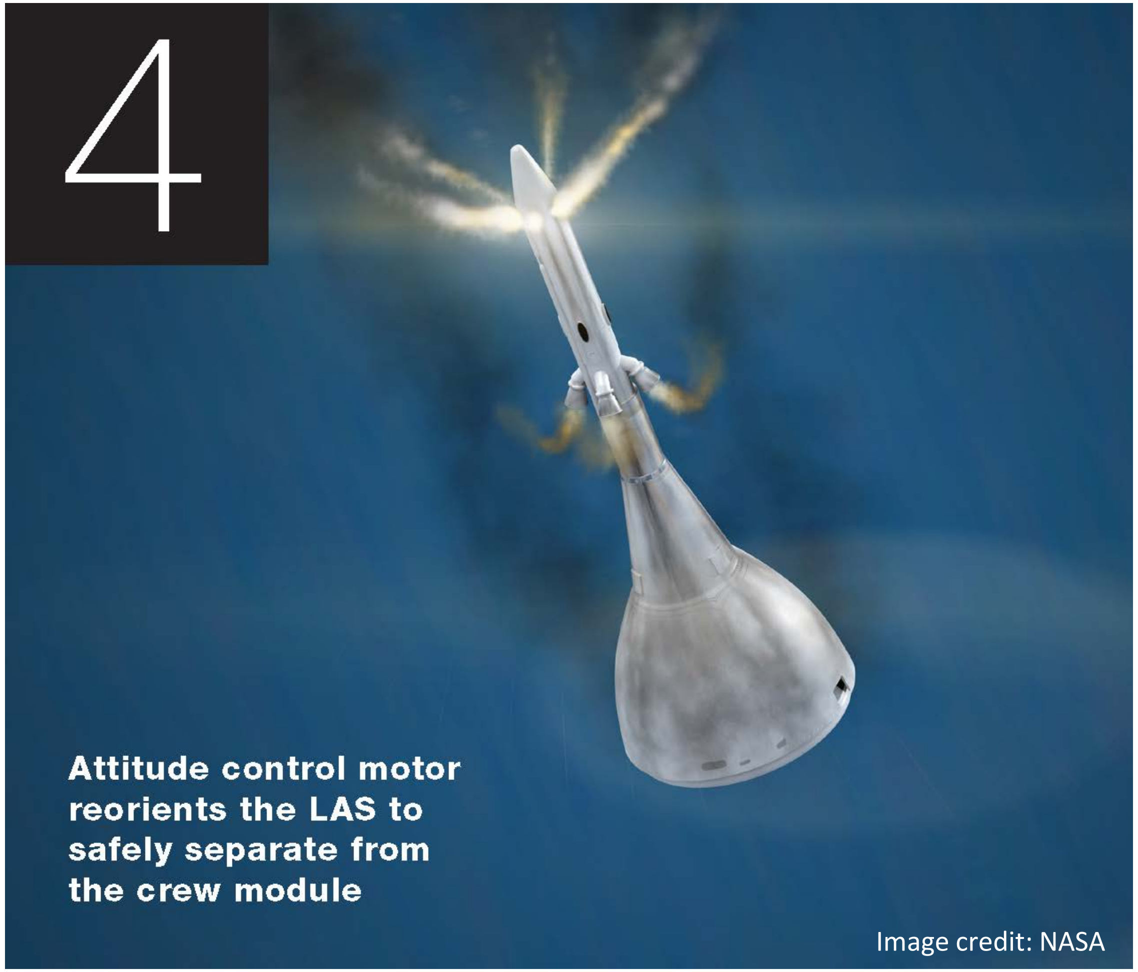
- Test condition target
  - Dynamic pressure: 620 psf
  - Mach Number: 1.15
  - Total Angle of Attack: 1°
- Test condition represents most challenging abort conditions

AA-2 Operations Concept
Flight Operations

Image credit: NASA

- Abort Motor provides 400,000 lbs thrust
- LAV gains more than 11,500 feet in 15 seconds

AA_2 Operations Concept
Flight Operations

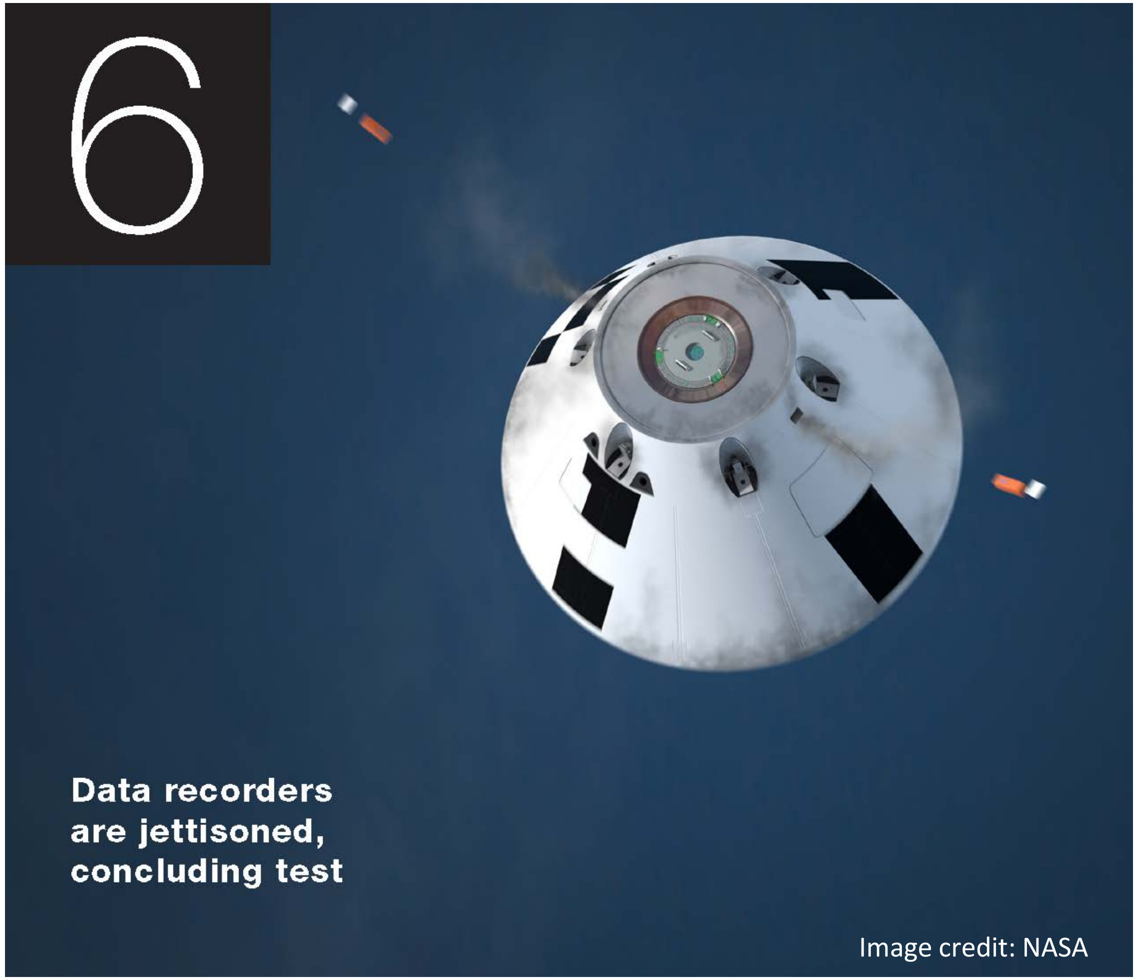


- Attitude control motor steers LAV during abort motor firing and during following coast
- At the end of the coast, ACM steers LAV heat shield forward in preparation for LAS jettison

AA-2 Operations Concept
Flight Operations

- During a normal ascent, the jettison motor will be fired to separate the LAS from the spacecraft just after second stage ignition
- During an abort, the jettison motor will be fired once the CM is in a heat shield forward orientation
- Following LAS jettison, the forward bay cover would normally be jettisoned to allow the parachute system (CPAS) to begin its operating cycle

AA-2 Operations Concept
Flight Operations



- All required data will be captured by the data recorders, so the crew module used for AA-2 will not deploy parachutes after the abort system is jettisoned
- The ejectable data recorders supplement the telemetry data received and recorded at multiple ground stations during the AA-2 mission
- Twelve (12) individual data recorders, all containing complete recordings of mission data, will be ejected in six (6) pairs at preprogrammed times after LAS Jettison
- Total test duration is less than three (3) minutes

AA-2 Mission Objectives

- There are a total of 38 Mission Objectives in 6 Categories
  - Abort Capability (2)
    - Demonstrate ability of LAS to propel the Launch Abort Vehicle (LAV) safely away from the Launch Vehicle
    - Determine critical performance parameters for the LAV at the test conditions
  - Dynamic Stability (5)
    - Determine stability & control characteristics of the LAV
    - Demonstrate heat-shield-forward flight stability
    - Determine CM dynamic response to LAS jettison
    - Determine the stability characteristics of the CM following LAS jettison
    - Demonstrate stability and control characteristics of the LAV due to the LAS
  - Structural Integrity (6)
    - Demonstrate the structural integrity of the LAS and all critical interfaces to the CM
    - Demonstrate LAS Faring Assembly structural integrity before reorientation
    - Obtain LAS structural loads data
    - Obtain LAS/CM interface structural loads data
    - Obtain CM primary structure loads data for all phases of the test
    - Obtain LAV/SM interface structural loads data

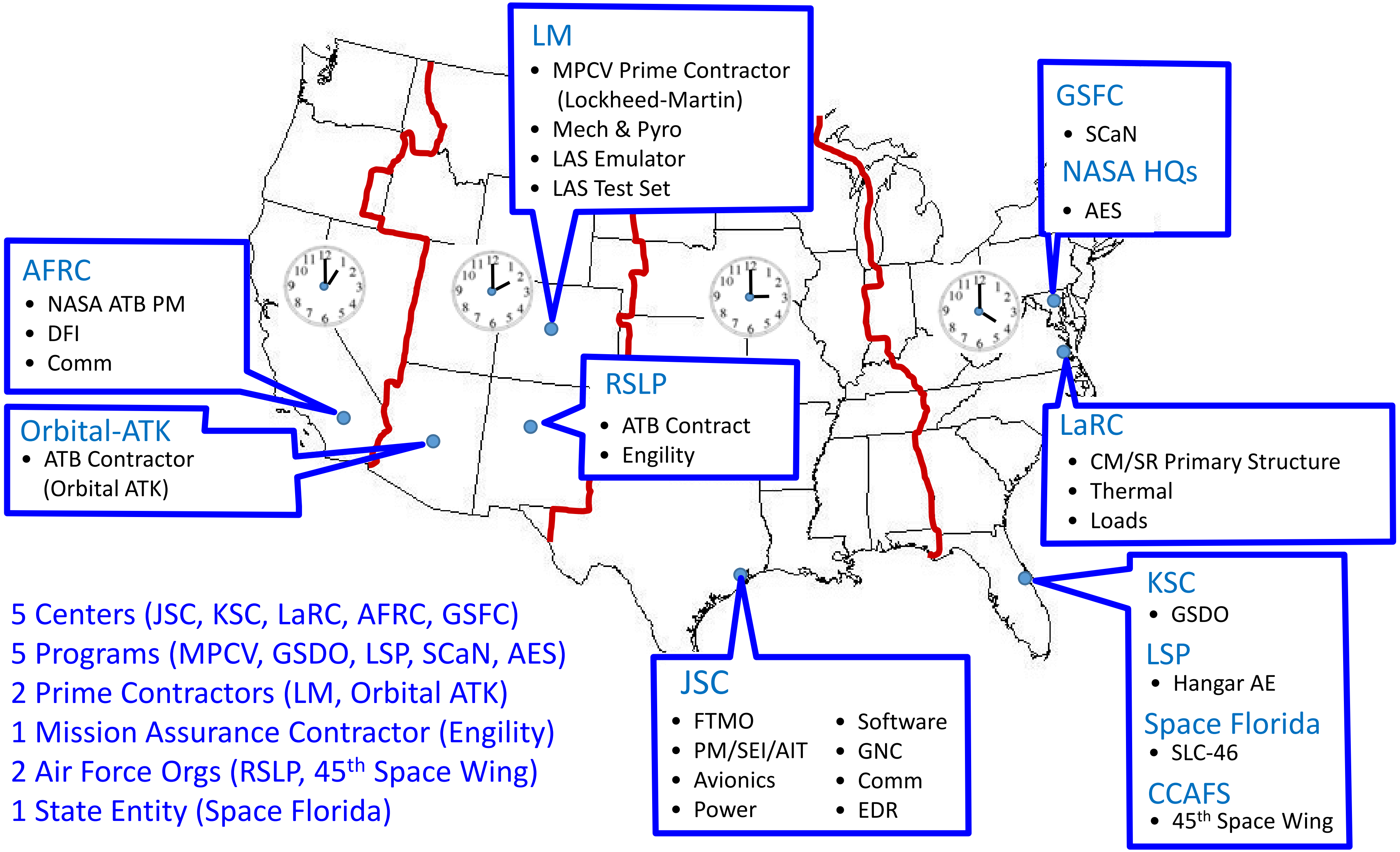
AA-2 Mission Objectives

- There are a total of 38 Mission Objectives in 6 Categories
  - Performance (4)
    - Determine the performance of the abort motor
    - Demonstrate the ability of the LAS to jettison from the CM
    - Determine separation trajectory of the LAS relative to the CM
    - Determine the performance of the Attitude Control Motor (ACM)
  - Separation (8)
    - Demonstrate SM/LAV separation at the selected angle of attack
    - Demonstrate the umbilical separation between CM and SM
    - Determine the CM and SM umbilical separation characteristics
    - Demonstrate CM/LAS separation
    - Obtain data of the separation of the LAS from the CM
    - Obtain data on water impact location of the LAS
    - Obtain data of the separation of the LAV from the SM
    - Demonstrate abort event sequencing from abort initiation through LAS jettison

AA-2 Mission Objectives

- There are a total of 38 Mission Objectives in 6 Categories
  - Environment (13)
    - Obtain data to anchor predictions of LAS/CM and LAS/SM interface vibrations from liftoff through LAS separation
    - Obtain data to anchor predictions of CM internal acoustic environment during abort phase of flight
    - Obtain external acoustic data on the LAS after liftoff and prior to LAS jettison
    - Obtain cavity acoustic data for the LAS Fairing Assembly / external CM cavity after liftoff and prior to LAS jettison
    - Obtain venting data during ascent
    - Determine thermal environments through LAS jettison
    - Determine low and high frequency acceleration environments after liftoff up to LAS jettison
    - Determine aerodynamic environments during all phases of launch and ascent, including LAV separation
    - Determine the aerodynamic environment of the CM post LAS jettison
    - Obtain subsonic dynamic aerodynamic data for the CM
    - Determine ascent aerothermodynamic environment during nominal and abort segments of flight
    - Determine aerodynamic and aerothermodynamic environments on the CM due to jettison motor plume impingement during LAS jettison
    - Determine critical environment and functionality data for the LAS hatch and associated mechanisms during an abort

AA-2 Mission Team: Locations



5 Centers (JSC, KSC, LaRC, AFRC, GSFC)
5 Programs (MPCV, GSDO, LSP, SCaN, AES)
2 Prime Contractors (LM, Orbital ATK)
1 Mission Assurance Contractor (Engility)
2 Air Force Orgs (RSLP, 45th Space Wing)
1 State Entity (Space Florida)

AA-2 Mission Team: Roles & Responsibilities

Image credit: NASA


Image credit: NASA


Image credit: NASA

- Johnson Space Center
  - Orion Program Office
    - Flight Test Management Office (FTMO)
      - Mission Management
    - Crew Module & Separation Ring Project Office (CSR)
      - Project Management
      - System Engineering & Integration
      - Safety & Mission Assurance
      - Avionics, Power, & Software
      - Guidance, Control, & Nav
      - Communications & Tracking
        - Engineering and Assembly, Integration, & Test
      - Ejectable Data Recorder
      - Assembly, Integration, & Test
      - CSR Operations

AA-2 Mission Team: Roles & Responsibilities

- Langley Research Center
  - Crew Module & Separation Ring Structure
  - Thermal Analysis
  - Loads & Structural Dynamics


Image credit: NASA

Image credit: NASA

Image credit: NASA

AA-2 Mission Team: Roles & Responsibilities

- Armstrong Flight Research Center
    - Abort Test Booster Acquisition
    - Flight Test Management Office Chief Engineer
    - Developmental Flight Instrumentation
    - Communications & Tracking
        - Management & Procurement

Image credit: NASA

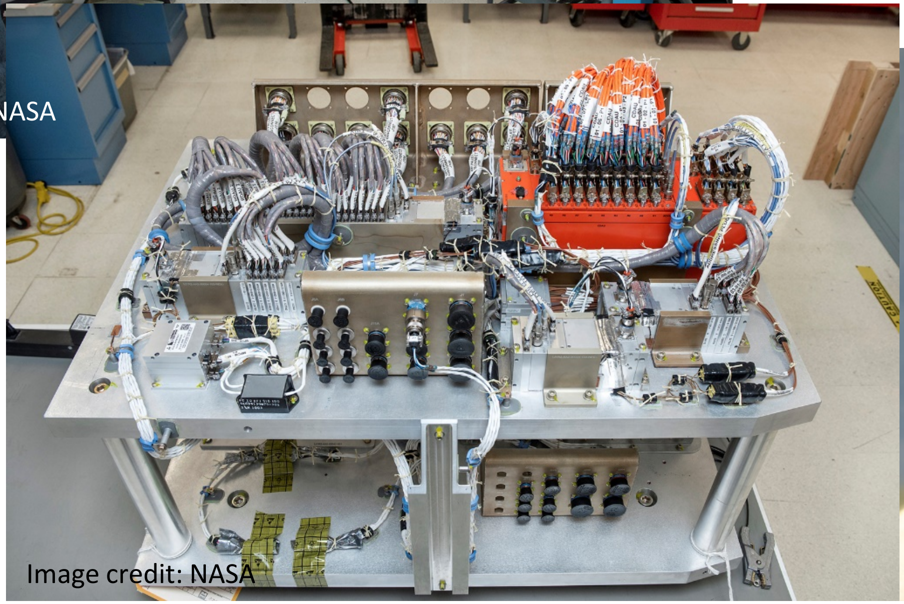


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Image credit: NASA

AA-2 Mission Team: Roles & Responsibilities


Image credit: NASA

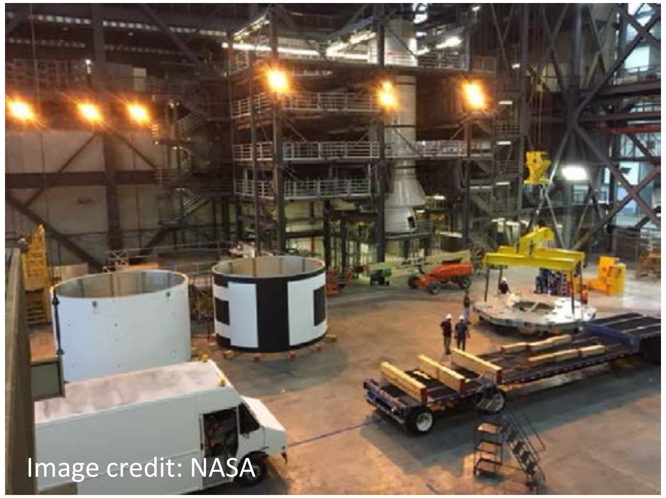
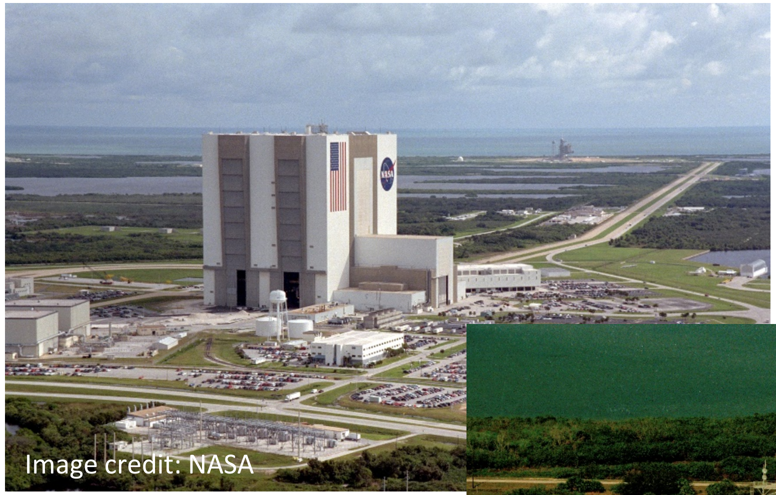


Image credit: NASA


Image credit: NASA

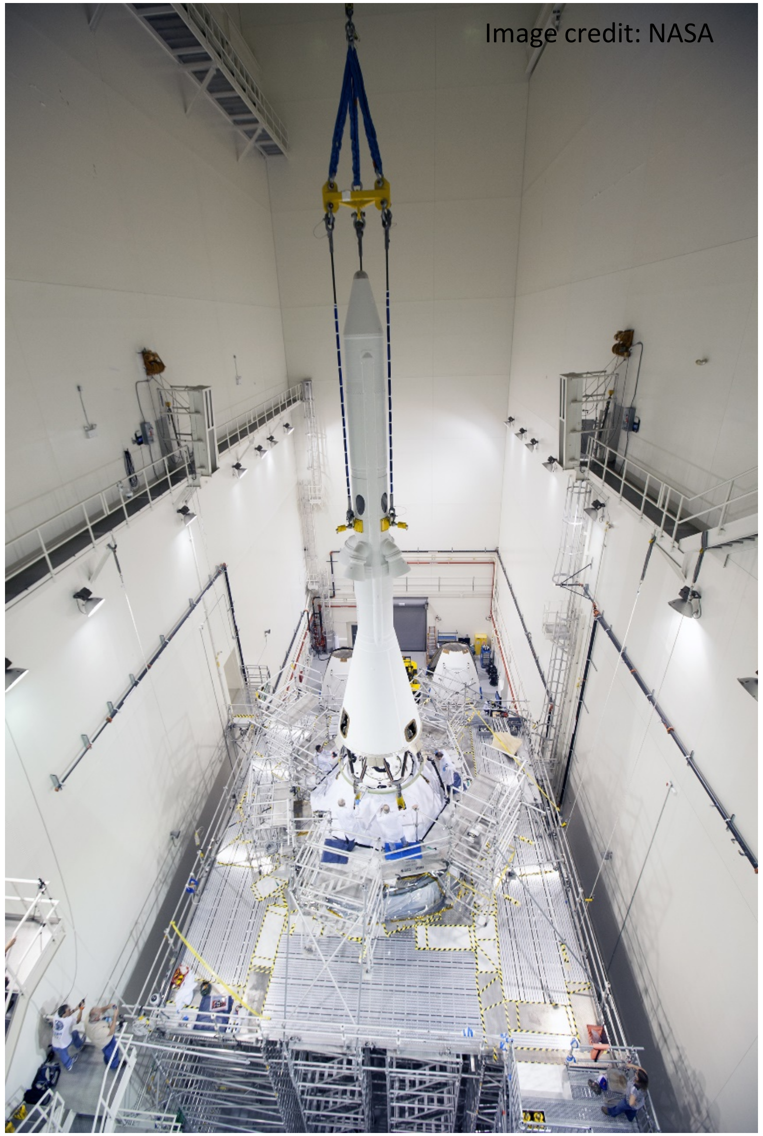
- Abort Test Booster
  - USAF Space and Missile System Center Launch Enterprise Directorate (SMC/LE), Kirtland AFB, NM
    - AF Rocket Systems Launch Program manages ATB Contract under Sounding Rocket Program 3 (SRP-3) Contract
    - SMC/LE also provides SR118 Solid Rocket Motor (LGM-118 Peacekeeper first stage)
    - ATB remains AF property at all times
  - Northrop Grumman Innovation Systems (formerly Orbital ATK), Chandler, AZ
    - Designs, fabricates, assembles and tests the ATB structures and systems
    - Integrates and tests DFI provided by NASA Armstrong Flight Research Center

AA-2 Mission Team: Roles & Responsibilities



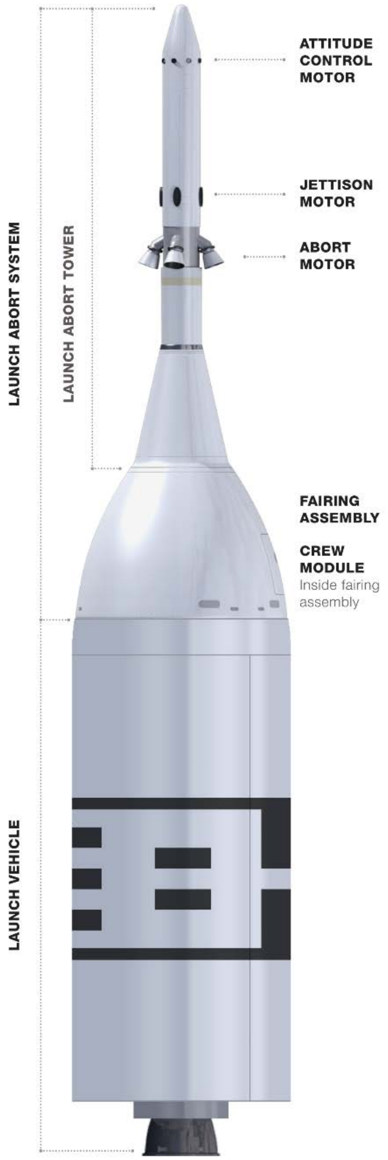
- Kennedy Space Center
  - Exploration Ground System Program
  - Ground Processing Facilities
  - Hangar AE on Cape Canaveral AFS
- Space Florida
  - Providing launch site (SLC-46)
  - NASA funding launch site and gantry modifications

AA-2 Mission Team: Roles & Responsibilities



- Lockheed Martin Space Systems
  - Launch Abort System (LAS)
  - LAS Emulator
  - Mech & Pyros
  - LAS Test Set

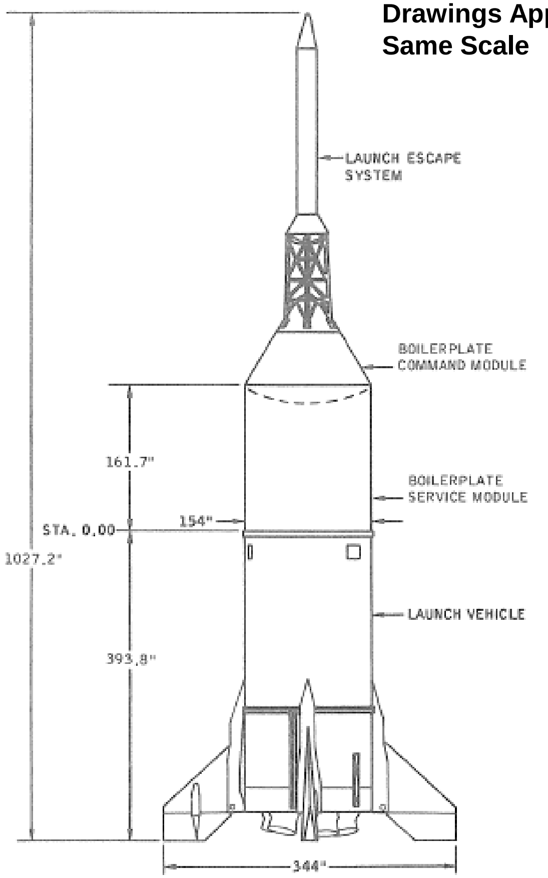
AA-2 Flight Test Vehicle



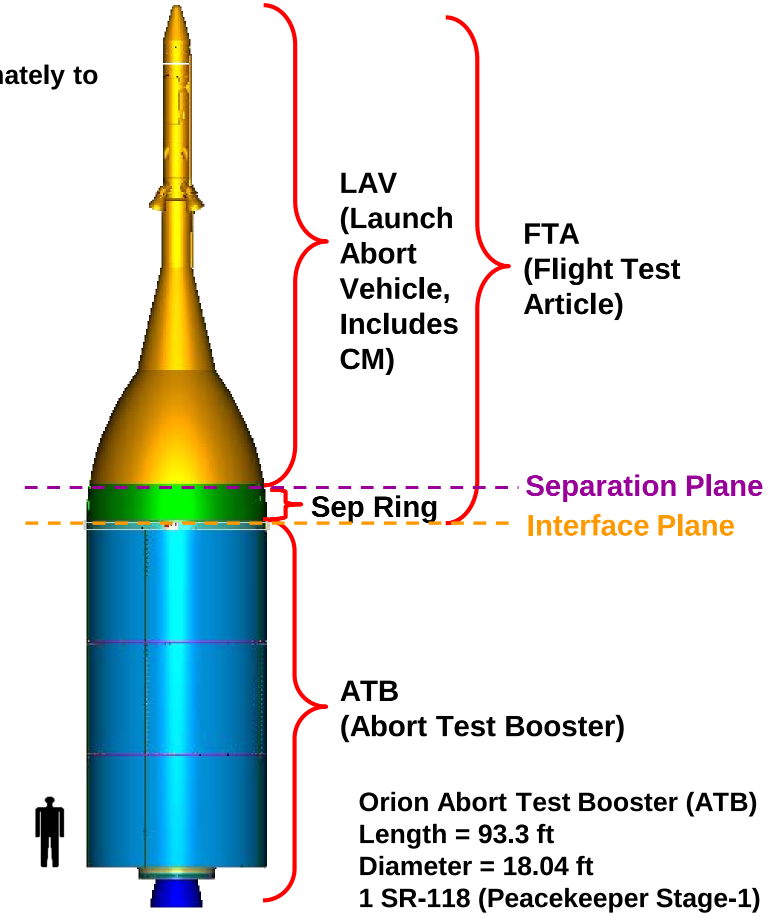
- The AA-2 Flight Test Vehicle (FTV) is composed of four modules
  - Abort Test Booster (ATB)
    - Lifts Flight Test Article (FTA) to desired test condition
  - Separation Ring (SepRing)
    - Attached to ATB
    - Simulates top of Orion Service Module (SM)
  - (Boilerplate) Crew Module (CM)
    - Mass properties & outer mold line (OML) simulation of an actual Orion Crew Module
  - Launch Abort System (LAS)
    - Production article
- The LAS and the CM together are referred to as the Launch Abort Vehicle (LAV)
- The LAV and the SepRing together are referred to as the Flight Test Article (FTA)
- The ATB and the SepRing together are referred to as the Launch Vehicle (LV)

AA-2 Flight Test Vehicle: ATB

Drawings Approximately to Same Scale



Apollo Little Joe II High Altitude Abort (12-51-2)
Length = 85.6 ft
Diameter = 12.833 ft
6 Algol Solid Rocket Motors (6 Scout Stg-1)
Total Propellant Weight = 114,000 lbs
Total Impulse = 24,408,000 lb-sec (sea level)

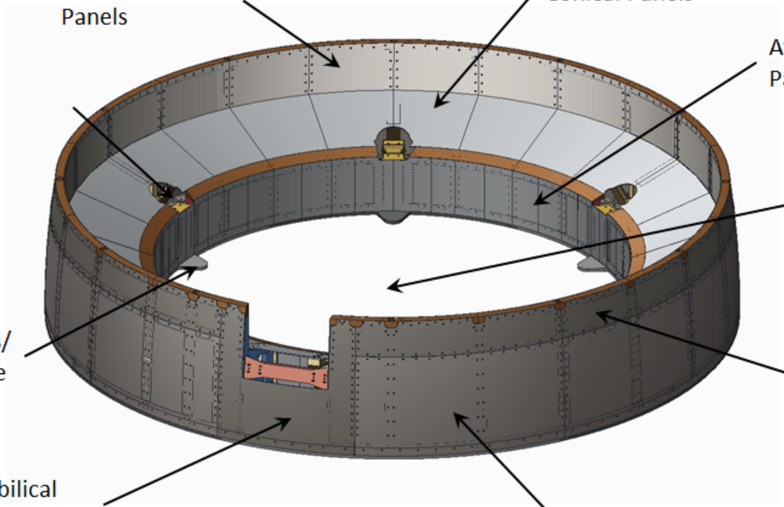


Orion Abort Test Booster (ATB)
Length = 93.3 ft
Diameter = 18.04 ft
1 SR-118 (Peacekeeper Stage-1) Solid Rocket Motor
Total Propellant Weight = 100,000 lbs (approx)
Total Impulse = 24,500,000 lb-sec (sea level) (approx)

Slightly Higher Total Impulse than Apollo Little Joe II High Altitude Abort Vehicle 12-51-2

- Powered by SR118 Solid Rocket Motor
  - First stage of LGM-118 Peackeeper ICBM
- Three tiered aeroshell with aft close-out panels
  - Same diameter as Orion Service Module Subsection (18.04 ft/5.5 m)
- Thrust reaction structure, ballast, and payload interface plate
  - Carry loads between the SR118 and the Sep Ring
- ATB guidance and control steers to desired trajectory through Abort Initiation
- Hosts ATB & SepRing DFI System
- Hosts a separate digital video system for capturing and telemetering the LAV separation at abort

AA-2 Flight Test Vehicle: SepRing



- Provides the structural and umbilical interfaces to the CM that are to be provided by the Orion Service Module
- Bolted down to the ATB payload interface plate
- Attached to the CM through six Orion production retention and release (R&R) pyro-mechanisms

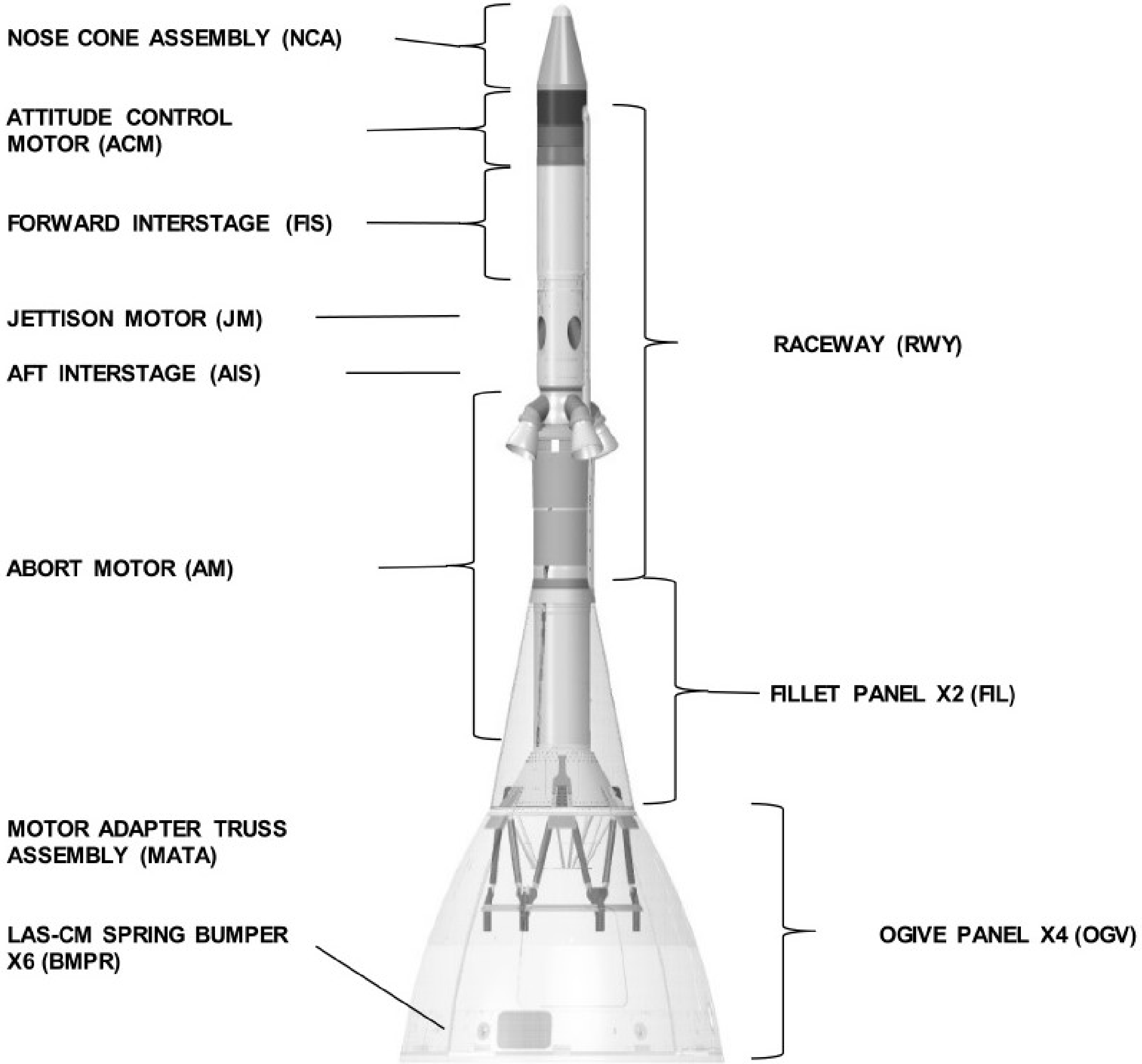
AA-2 Flight Test Vehicle: CM


Image credit: NASA


Image credit: NASA

- Outer mold line (OML) & mass properties simulate manned Orion Crew Module
- Contains test specific avionics; guidance, nav, & control; DFI & comm; and related systems
- No parachutes (CPAS)
    - Will not be recovered post test
    - CM test complete upon ejection of 12 ejectable data recorders

AA-2 Flight Test Vehicle: LAS

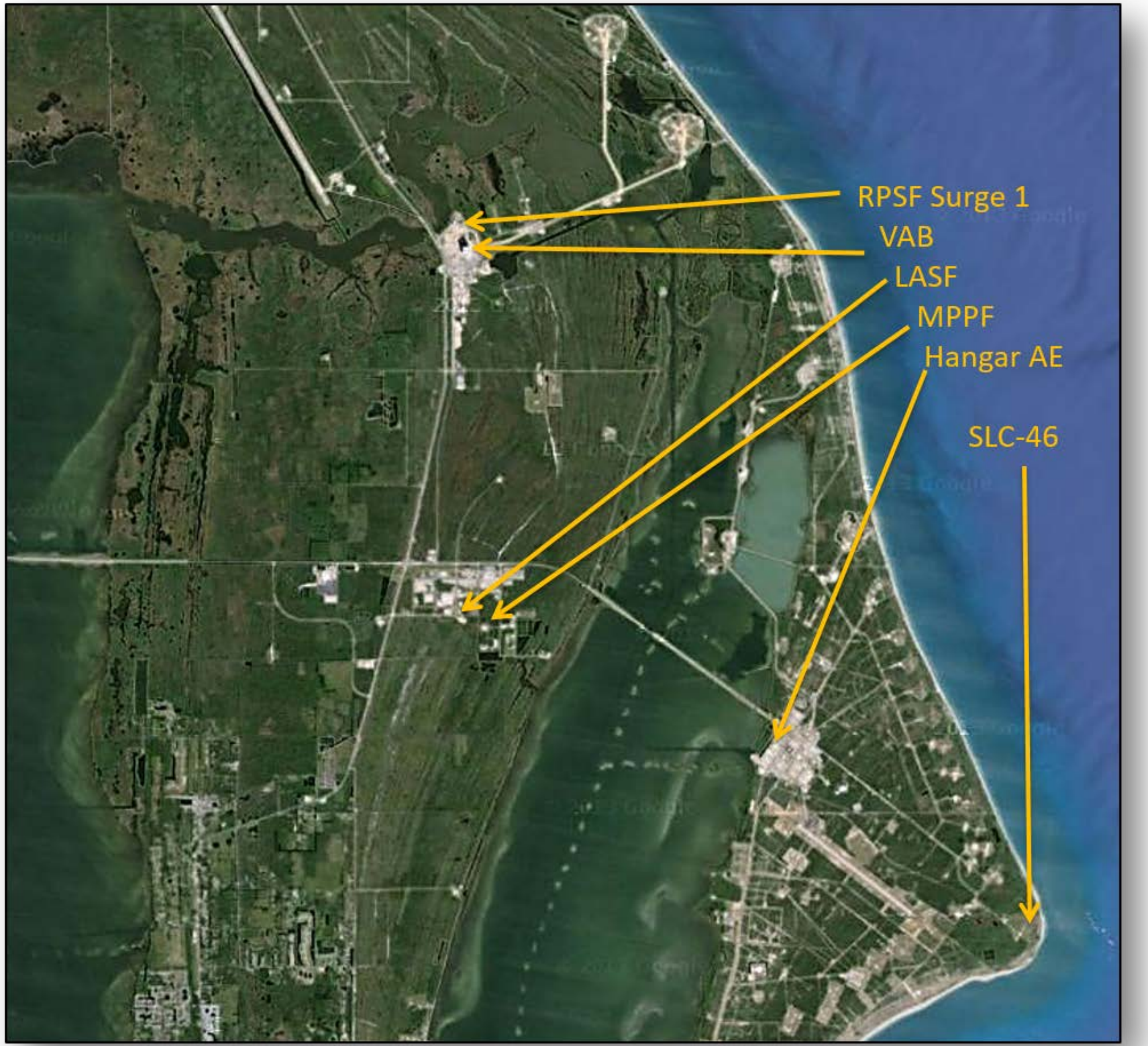


- Reverse Flow Abort Motor (AM)
  - ~400K lbs thrust to safely separate CM from failing launch vehicle
- Attitude Control Motor (ACM)
  - Gas generator with 8 proportional valves around its circumference
  - Can exert up to 7,000 lbs steering force
- Jettison Motor
  - During a normal ascent, safely separates the LAS from the spacecraft shortly after second stage ignition
  - During an abort, separates the LAS from the CM after the ACM reorients the CM to fly heat shield forward
  - LAS jettison is required to enable deployment of the parachutes (CPAS)
- LAS Fairing Assembly
  - Lightweight composite structure
  - Isolates CM from heat, aero loads, and acoustics during normal ascent and aborts

AA-2 Flight Test Vehicle: DFI

- LAS
  - Signal conditioning
    - 4 Remote Data Acquisition Units
  - 458 individual sensors
  - Telemetry antennas
- CM
  - Signal conditioning
    - 1 Master Data Acquisition Unit
    - 4 Remote Data Acquisition Units
  - 271 individual sensors
  - Telemetry transmitter with additional telemetry antennas
- SepRing
  - 85 individual sensors
- ATB
  - Signal conditioning
    - 1 master and 1 remote data acquisition unit
  - 76 individual sensors
  - Telemetry transmitter & antennas
  - Digital video system for LAV/LV separation

AA-2 Operations Concept
Ground Processing Facilities



KSC

<u>VAB</u>
SR118 Container Transfer
ATB Aeroshell Processing
ATB Equipment Storage

<u>LASF</u>
CM-LAS Tests
LAS Integration to CM

<u>MPPF</u>
CSR Post-Ship Activities

<u>RPSF Surge 1</u>
ATB Processing

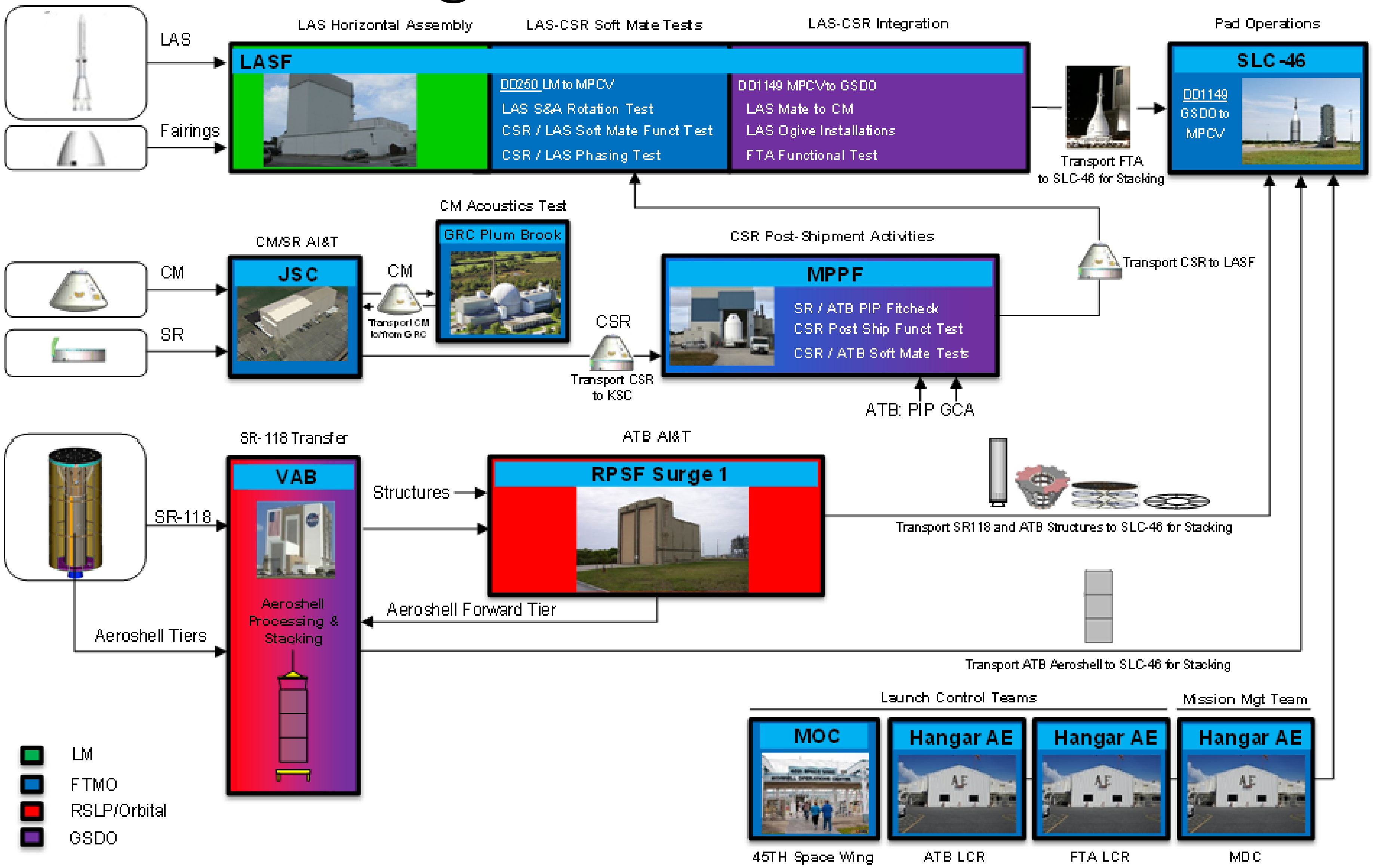
CCAFS

<u>Morrell Operations Center</u>:
Range Operations

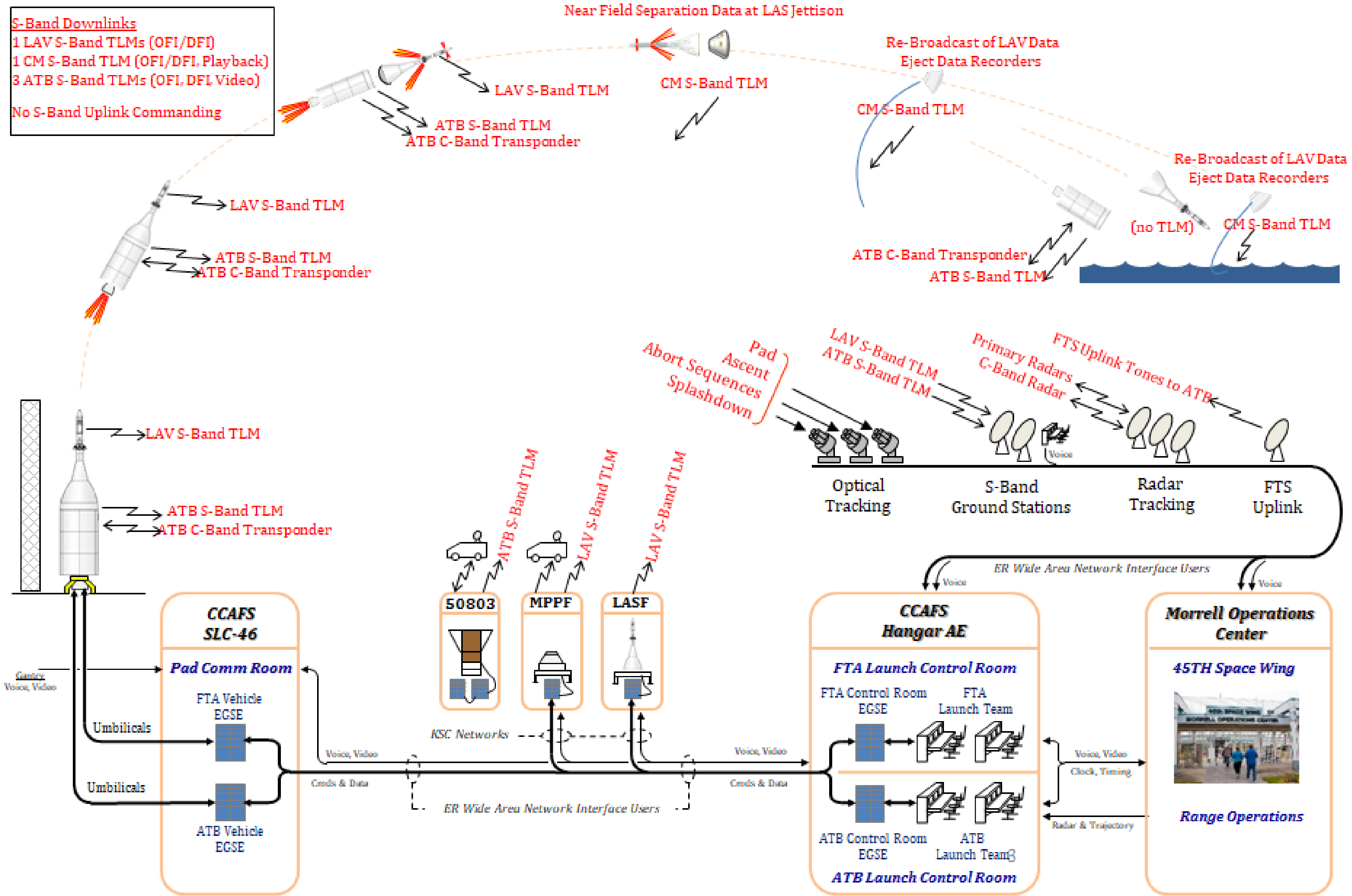
<u>Hangar AE</u>:
ATB & FTA Launch Operations

<u>SLC-46</u>:
Launch Site

AA-2 Operations Concept
Ground Processing Flow



AA-2 Operations Concept
Test Data



- 2 telemetry (TM) systems & 1 digital video system
- Separate Flight Test Article (FTA) and ATB control rooms
- 4 TM ground stations
- Multiple optical trackers for high resolution video coverage

AA-2 Operations Concept
Ejectable Data Recorder Recovery

- Each data recorder contains a GPS receiver and after ejection it periodically reports its position via an Iridium satellite link
- AA-2 Operations Team Members will retrieve the recorders from the surface of the ocean once the range is declared safe for retrieval operations

Ascent Abort 2 Mission Video

Video credit: NASA

Questions?

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